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Investigating the Optical Properties of Doped Amorphous Glasses

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ABSTRACT

We have studied the effects of eribium (Er) doping on As_2S_3 films as well as the changes to their optical properties when exposed to UV radiation. Variable-angle spectroscopic ellipsometer from J. A. Woollam Co., Inc. was used to obtain ellipsometric spectra. The ellipsometric spectra were taken for a series of As_2S_3 films doped with different Er concentration. We find that the index of refraction changes approximately by 2% with Er doping, but it changes over 5% when a specific sample is exposed to UV radiation. In addition, the extinction coefficient changes as a function of the doping, indicating a reduction in the band gap as Er is introduced to the As_2S_3 film. We also find that the thickness of each sample decreases by about 2-3% as they are exposed to UV radiation.

INTRODUCTION

As_2S_3 glassy films are amorphous semiconductors and these materials have high transparency throughout near-infrared and infrared spectral region.[1] These materials can be used in optical storage media like compact disk ROMs (CDRs) and digital versatile disks (DVDs)[2] because of its photoinduced metastabilities.[2]

As_2S_3 amorphous films change their optical and chemical properties under photoexposure. These properties allows for selective chemical etching, which makes them suitable for holographic laser lithography.[3, 4] Therefore, these films have been used for the fabrication of three-dimensional photonic crystals.[1] These photonic crystals are optical equivalent of semiconductors.[5] Since it is essential to have a high refractive index to fabricate high quality photonic crystals, As_2S_3 amorphous films fit this criteria.

Although there have been several studies reported, related to their growth and structural properties, their optical properties have not been studied extensively. In particular, the dielectric functions of these materials have not been reported, and the few studies that have been reported have been limited to the transparent region. In addition, only a few studies have reported the changes of As_2S_3 films as they are exposed to UV radiation. In this particular study, we have therefore systematically determined their indices of refraction as a function of the Er-doping concentration as well as probed the changes associated with the index of refraction as these materials were exposed to UV radiation.

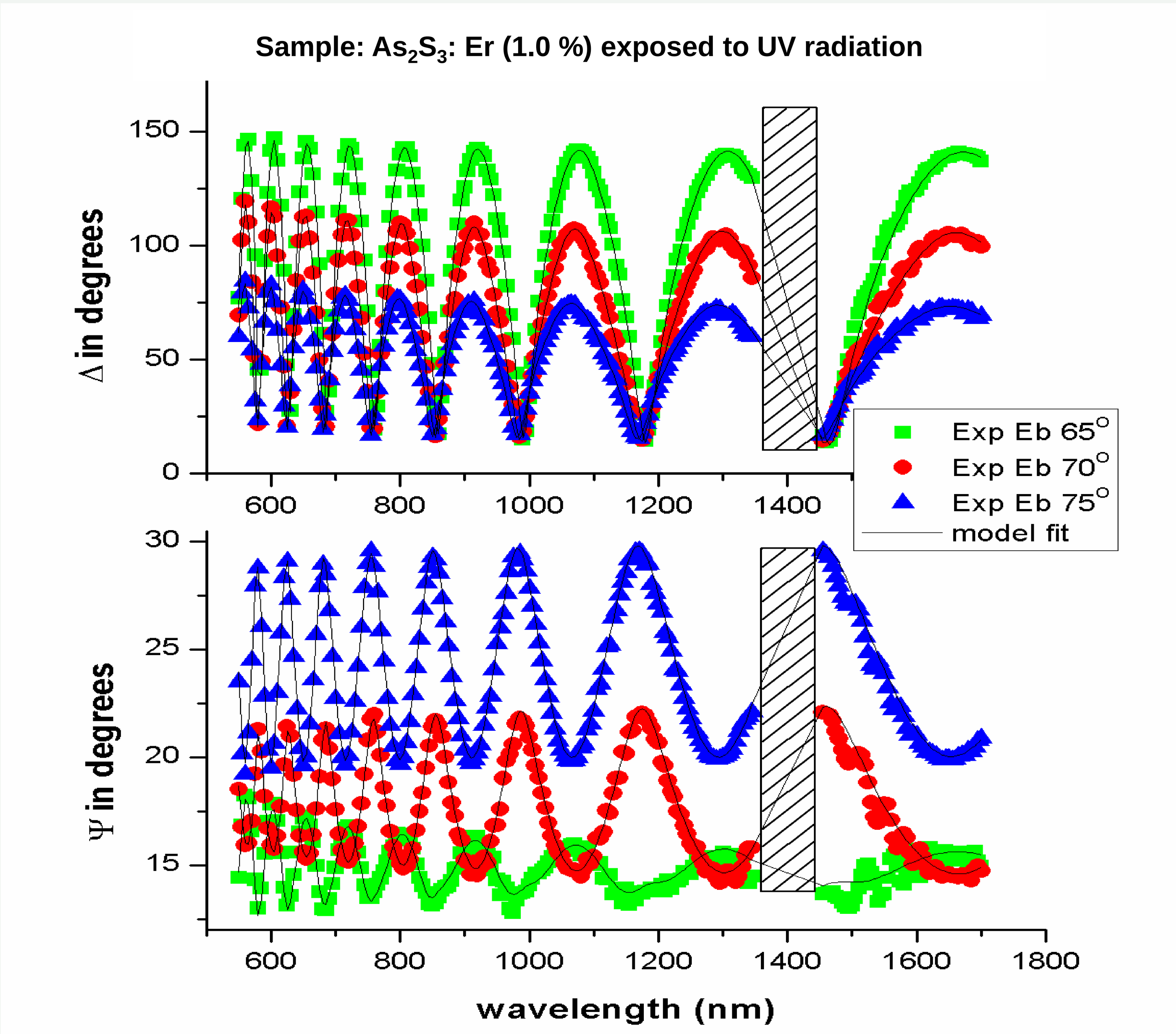

Figure 1. Experimental data and Cauchy model. No data points were available in the shaded region because of the absorption of light by the fiber that is coupled to the instrument.

EXPERIMENTAIL DETAILS

The As_2S_3 films were fabricated at the University of Karlsruhe, Karlsruhe, Germany. Glassy As_2S_3 was thermally evaporated in a high-vacuum evaporating chamber at temperature of T=385°C, under an evaporation pressure of 5×10^{-6} mbar (1 bar = 100 000 Pa), and with a rate, measured with a quartz microbalance, of approximately 6 nms^{-1}.[1] All of the sample were grown on glass substrates.

The doping concentration of Er in As_2S_3 was 0.0%, 0.5%, 1.0% and 2.0%. Variable-angle spectroscopic ellipsometer from J. A. Woollam was used in a vertical sample mount configuration. For each sample Ψ and Δ were measured at angles 65º, 70º, and 75º in the range 200-1700nm.

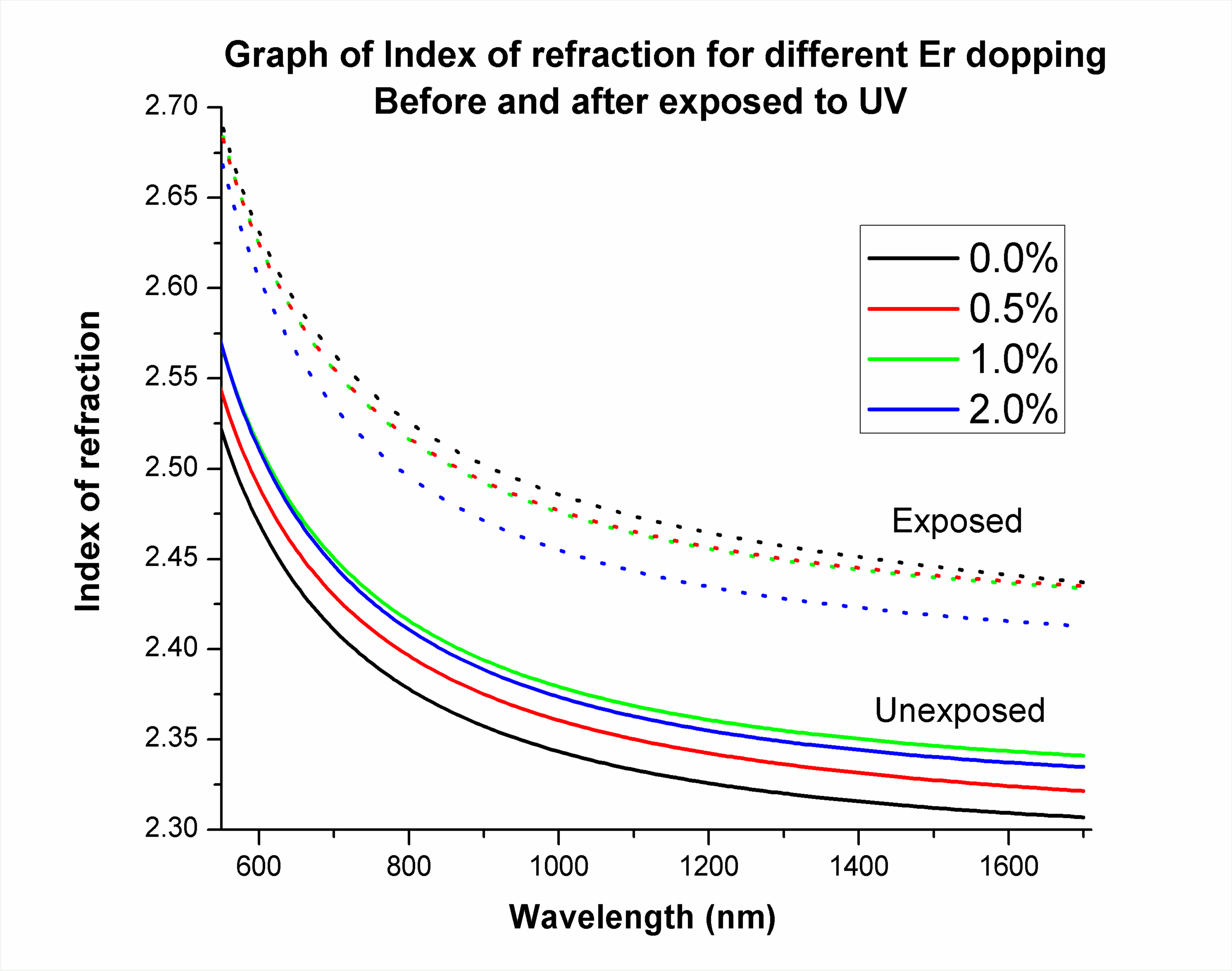

Figure 2. Index of refraction for exposed and unexposed samples. Index of refraction of exposed films increases by approximately 5%.

RESULTS AND ANALYSIS

The ellipsometry spectra obtained for a representative sample of As_2S_3 is shown in Fig. 1. We use a Cauchy model to determine index of refraction (n(λ)) [Fig. 2] and the thickness [Fig. 3] for each sample in the transparent region i.e. λ>550nm. As evident in Fig. 2, the Cauchy model dictates that n(λ) increases as a function of Er doping concentration. It must be noted that this increment is approximately 2% [Fig. 2]. Furthermore n(λ) increases when the samples are exposed to UV radiation. After the samples were exposed to UV radiation there is no significant correlation between the change in index of refraction with the concentration of Er in As_2S_3 [fig. 2].

The thickness of the samples decreased when they were exposed to UV radiation [Fig. 3], indicating a contraction of the As_2S_3 :Er layer due to UV radiation. The contraction is greater for 0.5% Er and 1.0%Er doping but it is less for 0.0%Er and 2.0%Er doping. The contraction see in all samples indicates that the As_2S_3 films will contract when exposed to UV irrespective of the Er doping concentration.

After determining the n(λ) in the transparent region using the Cauchy model, we next model the absorption region using the General Oscillator model (GenOsc) . The index of refraction and the extinction coefficient for the entire range (λ=200-1700nm) was found from the (GenOsc) [Fig. 4]. As shown in Fig. 3, the bandgap red-shifts with the increase in concentration of Er. This indicates the decrease of bandgap as As_2S_3 is doped with Er [Fig 3]. The effect of UV radiation on the bandgap could not be determined in this experiment because the bandgap increased for some samples while it decreased for others. A further study is required to confirm the effect of the UV radiation on the bandgap, with change in concentration of Er doping.

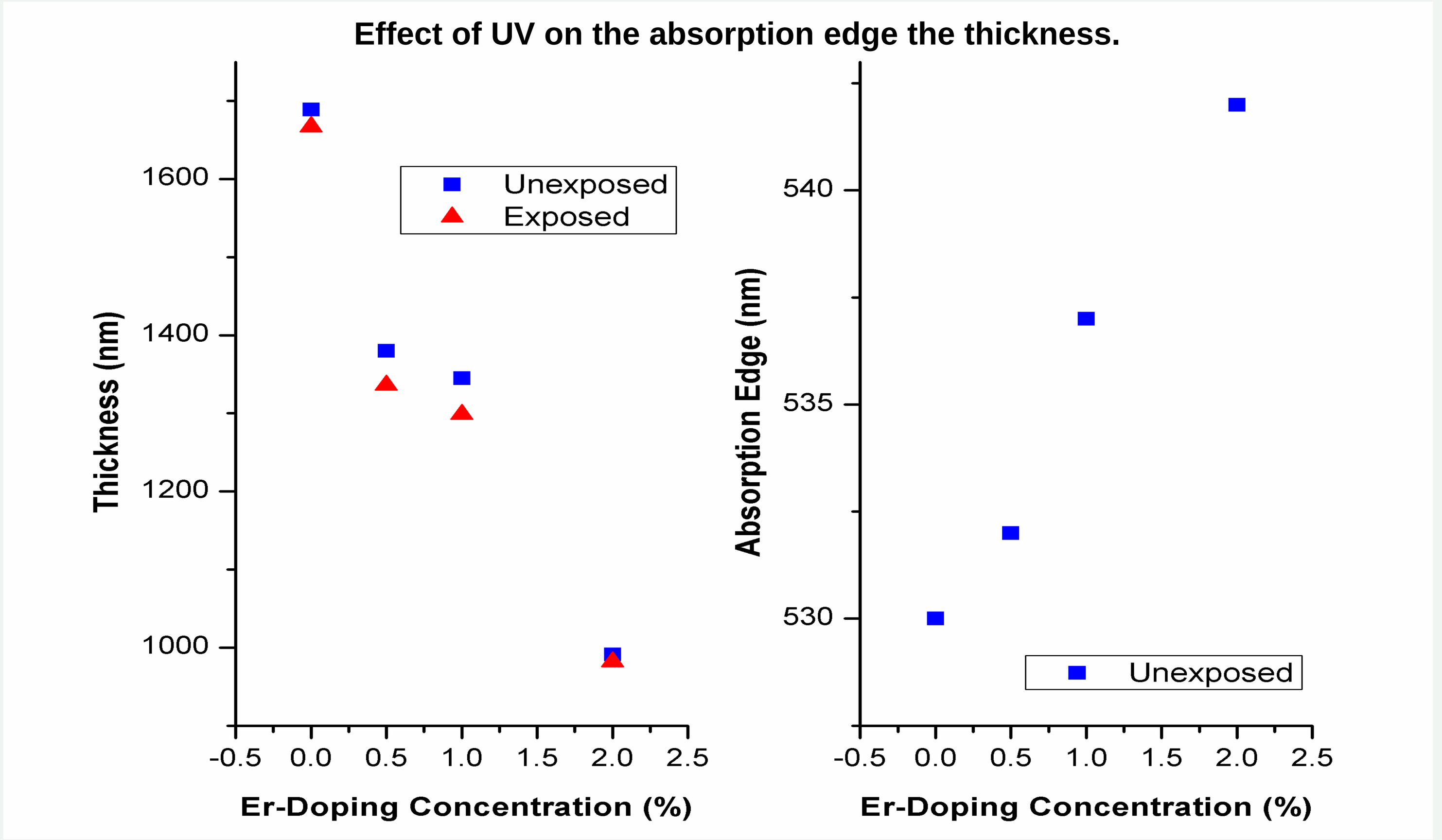

Figure 3. Effect of Er doping and UV on the thickness of the film and the absorption edge.

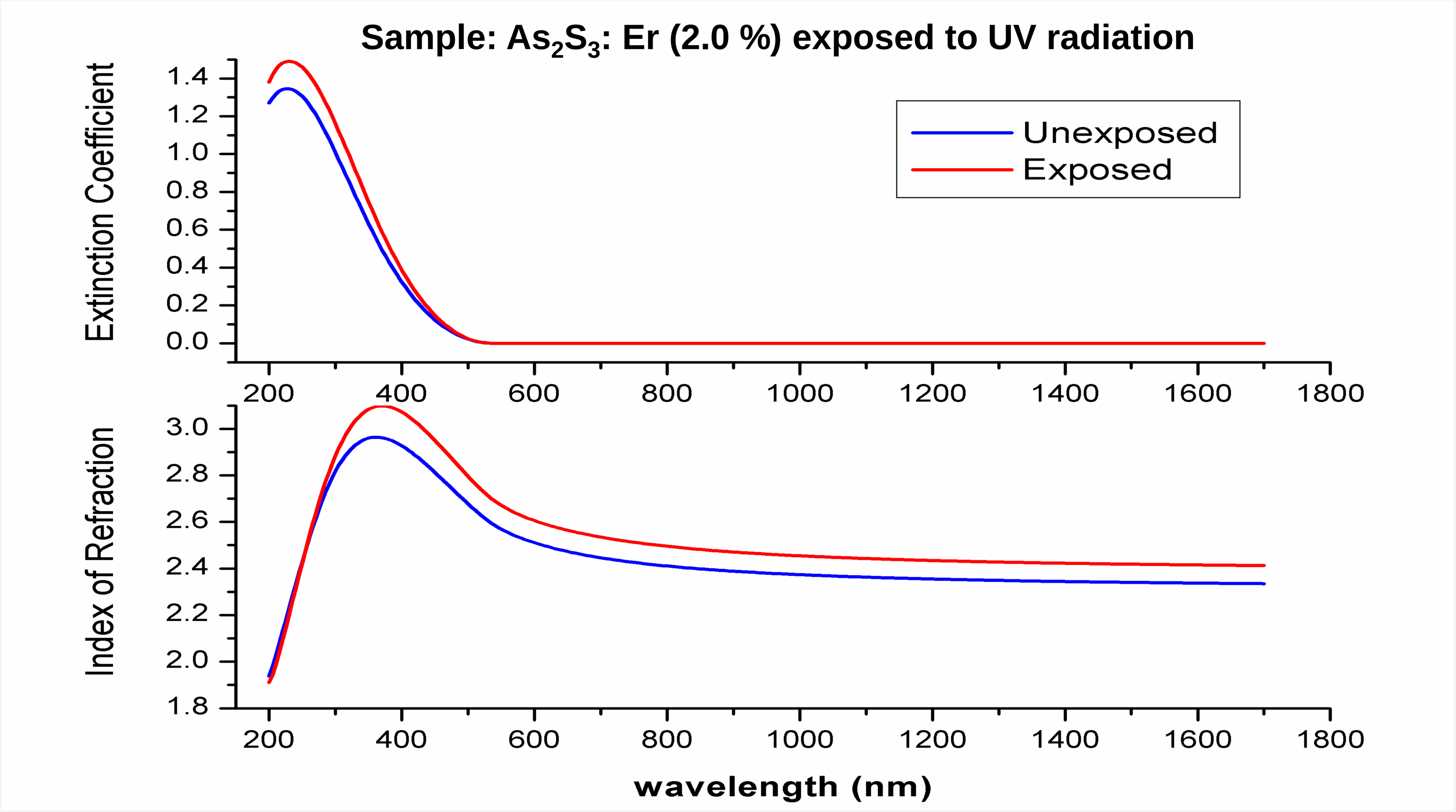

Figure 4. Extinction coefficient and index of refraction for the entire range (λ=200-1700nm).

CONCLUSION

It was found that the index of refraction (n) of As_2S_3 amorphous films increased by 2% when doped with Er but *n* increased by approximately 5% after the samples were exposed to UV radiation. Thickness of the As_2S_3:Er layer decreased by 2-3% after exposure to UV radiation. The band gap reduces as a function of the Er doping concentration. The exposure to UV radiation does not significantly change the band gap.

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